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*Notes on Photographs of Nebulæ taken with the 60-inch Reflector of the Mount Wilson Solar Observatory, by G. W. Ritchey, Assoc. R.A.S.*

(*Letter accompanying a further present of photographs to the Society.*)

A few days ago I sent you by express a third box of transparencies on glass from negatives which I have recently secured with the 60-inch reflector. The enlarged positive of the globular cluster Messier 13 Herculis is on a 16 × 20 inch transparency plate; those of the nebulæ Messier 33, H. v.24, N.G.C. 6960, and N.G.C. 6992 are on 14 × 17 inch plates; those of the Ring nebula in Lyra and Messier 64 are on 8 × 10 inch plates.

The negative of Messier 13 Herculis was exposed for 11 hours. To lessen the *coma* of the images of the outlying stars (for the cluster is shown to be nearly 30 minutes of arc in diameter) the aperture of the large mirror was reduced to 50 inches. A Seed 23 plate was used. In the resulting negative the small star-images are 1″·03 in diameter. Miss Ware has counted the stars shown in successive zones, in order to determine, if possible, the law of distribution. Professor Chrétien and Miss Ware have continued this investigation by photometric means, in order to include the large central region where counting is difficult or impossible on account of the superposition of the star-images: this work is not yet completed. It is expected to continue the investigation in the case of the clusters Messier 3 and Messier 92, excellent negatives of which have been secured. Miss Ware's counts of Messier 13 show 26,700 stars outside of the region or zone where apparent superposition begins. An attempt will be made also to determine the magnitude of the faintest stars shown in this photograph.

Far more important, it seems to me, is the photograph of the spiral nebula Messier 33 Trianguli, which was secured with $8\frac{1}{2}$ hours' exposure, with fairly good seeing. This nebula exhibits to a marked degree all of the invariable characteristics of the spiral nebulæ, namely, the well-marked nucleus, the bright convolutions, which apparently consist of nebulosity which is condensing into thousands of nebulous stars; the numerous dense groups of nebulous stars; the dark rifts of complicated structure which separate and intersperse the bright convolutions, these dark rifts, like those in the Andromeda nebula, showing a flocculent, curdled structure strikingly similar to that of the dark rifts which Professor Barnard has photographed in the Milky Way. All of these characteristics are present in all of the large spirals which I have photographed. They distinguish the spiral nebulæ in a most marked degree from all the other classes of nebulæ. The region shown in the positive is about $28 \times 34$ minutes of arc in extent, corresponding to approximately $2\frac{1}{2} \times 3$ inches on the original negative; in this area Miss Ware has counted 26,434 nebulous stars in the convolutions, together with 2348 non-nebulous stars which are apparently superposed. These counts give some idea of the exquisitive performance of the 60-inch reflector.

The photograph of the spiral nebula Messier 64 Comæ Berenicis is also most interesting, because this is the only spiral I have photographed in which the nebulous stars are present only in the central parts of the nebula, and are entirely absent in the outer convolutions. This is beautifully shown in the positive. In marked contrast to this are the spirals Messier 81 Ursæ Majoris and the Great Nebula in Andromeda, in both of which the central regions contain no nebulous stars whatever (so far as the 60-inch photographs can show), and in both of which the outer parts of the convolutions contain thousands of nebulous stars. In most of the large spirals, however, the nebulous stars are present in all parts of the convolutions, from the central nucleus to the outer extremities.

Thus the 60-inch photographs show not only that the spiral nebulæ are distinguished by many sharply-marked characteristics from all other classes of nebulæ, but that the spirals themselves exhibit marked differences from each other in regard to the distribution of the nebulous stars,—differences which possibly correspond to successive stages of development.

The photograph of the "straight ray" nebula H.V. 24 is also most interesting and instructive. The fact that there are 50 or more nebulous stars shown in and immediately around this nebula, together with the fact that no nebulous stars are shown in my negative in any other class of nebulæ except the spirals, leave no doubt in my mind that this is a large spiral seen almost exactly on edge, and that the dark band crossing the large brilliant central condensation is the comparatively cool, thin edge of the spiral projected against the hotter and more brilliant centre.

N.G.C. 6960 and N.C.G. 6992 in Cygnus are the finest examples of filamentous nebulæ which I have photographed. Almost equally remarkable examples of this class are the "Crab" nebula in Taurus (of which I sent you a positive) and the nebulosities around Maia and Merope in the Pleiades. The negative of 6960 was exposed for $6\frac{1}{2}$ hours; that of 6992 for $10\frac{1}{4}$ hours.

The positive of the Ring nebula in Lyra which I send is from a negative secured this summer with the new plate-carrier and with good seeing. The exposure was 45 minutes on a Seed process plate. This photograph is considerably sharper than the one I sent some months ago. Not only is a great amount of intricate structure shown in the ring, but the exposure was long enough in this case to show also the five or six principal protuberances outside of the ring, as well as considerable structure in the two light bands which cross the dark central space, and which lie roughly parallel to the major axis of the ellipse.

*Mount Wilson Solar Observatory :*
1910 *September* 17.

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*The Total Solar Eclipse of* 1910 *May* 8. By Walter F. Gale. (Plate 22.)

In order to secure, if possible, some useful results from the total solar eclipse of 1910 May 8, I journeyed to Tasmania, taking a camera with $3\frac{1}{2}$-inch Ross lens of 19 inches focus for corona pictures and a diffraction grating camera of $1\frac{1}{2}$ inches aperture and 26 inches focus. Unfortunately the eventful afternoon was quite overcast and light rain fell as totality approached. Owing to the dull light of the overcast sky the contrast, as the eclipse progressed, was not very marked until within ten minutes of totality. A very deep gloom then supervened, which during totality was estimated as nearly equal to the darkness of a bright moonless night.

On the night of Wednesday, May 11, the R.M.S. *Corinthic* arrived at Hobart, and passengers reported having had a magnificent view of the eclipse when about 480 miles from port. I interviewed thirteen witnesses, and verified the statements made by them to Reuter's agent, who cabled their impressions of the eclipse to the International Press. Their description of the corona, given in all good faith, was quite at variance with that I had anticipated, and I have since proved that fatigue of the retina will explain the departure from the facts in each case. Apparently no one on board was provided with dark glasses, and nearly all gazed at the crescent sun. Hence when totality was reached all they perceived was a rose- or reddish-coloured ring about 3′ in extent surrounding the dark body of the Moon, and outside this a pearly light extending outwards not more than 5′ of arc. All agreed there were no prominences, streamers, rays or plumes visible at any part of the circum-

ference. None of the *Corinthic* observers gave the corona a total greater extent than one-fourth the apparent diameter of the Moon's dark disc. A number of passengers were provided with cameras, but all exposed their plates before totality was reached. I have had some correspondence with the master of the steamer and others, and learn that all the plates were quite useless, and that no special notes were made. Fortunately one town in Tasmania was favoured with a clear interval of sky during the critical period of the eclipse, and lucid descriptions have been sent me by several trustworthy witnesses. Most important of all, perhaps, are two prints of photographs sent me by Mr. A. G. Waterworth, headmaster of the State school at Queenstown, which I believe to be the only reliable ones taken of this eclipse. They demonstrate that the type was normal, and quite unlike that indicated by those on the *Corinthic*.

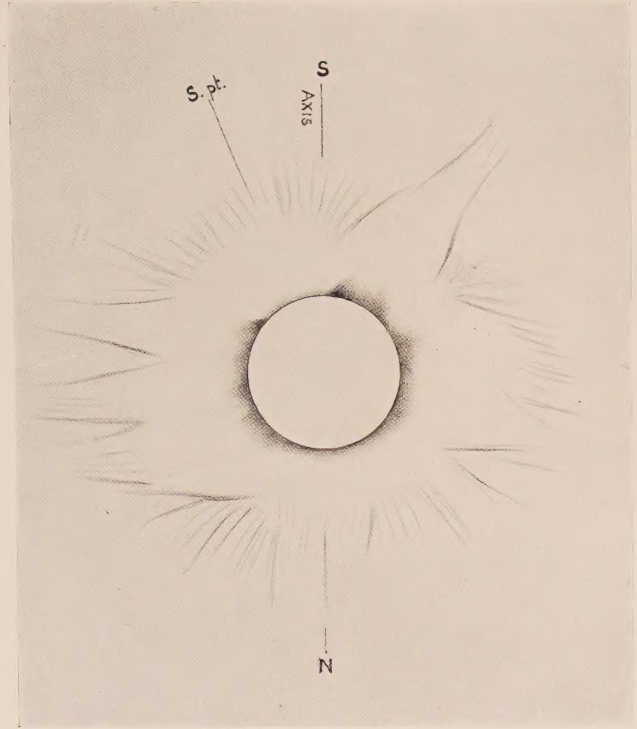
Mr. E. Carus Driffield, M.I.C.E., consulting engineer of the Mount Lyell Company, whom I met in Melbourne five days after the eclipse, furnished some accurate information of the phenomenon as seen by him at Queenstown. He has this week sent me the attached description and drawing, the accuracy of the latter certified to by Messrs. Cruickshank, Cox, Waterworth, and Macdougall. I send also annexed hereto the two photographic prints. That by the Rev. L. S. Macdougall and Mr James Boston has endorsed upon it, "Taken with a Thornton-Pickard half-plate camera (triple-extension), with back combination of lens removed. Diaphragm f. 22. Exposure two secs." This shows the inner corona very well, and exhibits the roots of the streamers. The second print was taken by Mr. Sargeant, but particulars of exposure are wanting. The camera was evidently of short focus, and the exposure relatively long. The corona is shown to extend about one diameter of the Sun, and the form to be that typical of the quiescent state of the solar surface.

*Waratah, Newcastle, New South Wales:*
1910 *July* 26.

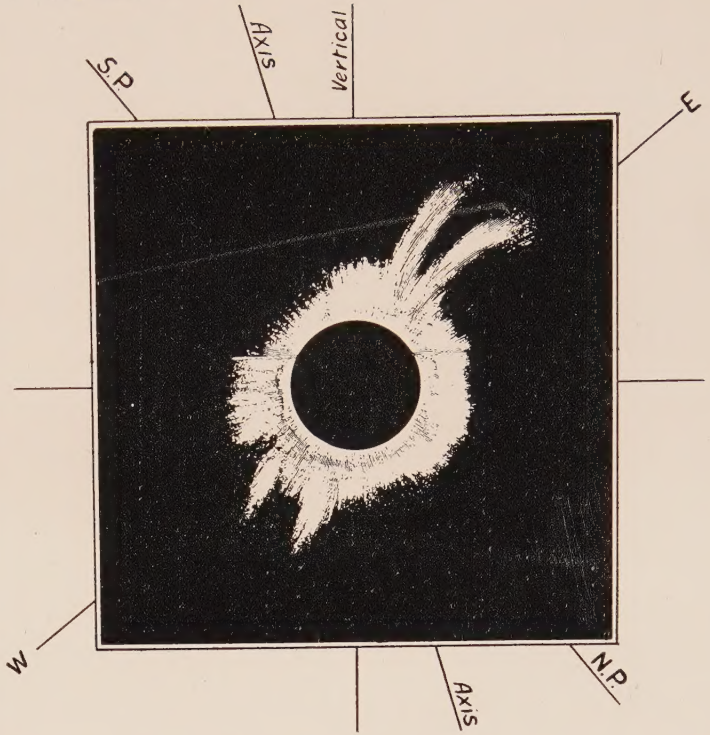
*Note by W. H. Wesley.*

The photographs being too small for satisfactory reproduction, I have constructed from them the sketch given on Plate 22. The inner corona is from the photograph by Messrs. Macdougall and Boston, the outer from the photograph by Mr. Sargeant. As the latter shows the outline of the terrestrial landscape, the vertex is obtained and the picture approximately oriented. The photograph showing the inner corona agrees so well with the other that I do not think there is much uncertainty as to its orientation. As the cameras were stationary, the Moon's disc is deformed in consequence of the diurnal motion, especially in the case of Mr. Sargeant's picture.

The corona seems rather to belong to the type intermediate




Sketch from Photographs.




Drawing by E. Carus Driffield.

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between maximum and minimum of solar activity. It strikingly resembles that of 1896, as photographed by Hansky in Novaya Zemlya, but the poles are reversed,—the N. pole of 1896 resembling the S. pole of 1910. Notwithstanding the small size of the images a considerable amount of detail can be made out, but I cannot detect the least trace of solar prominences in either of the photographs.

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*Notes on the Solar Eclipse as seen at Queenstown, Tasmania, Monday 9th May* 1910. By E. Carus Driffield, M.I.C.E.

(*Communicated by Mr. Walter F. Gale.*)

The day was very overcast, and steady rain fell until about 2·30 p.m. The Sun was hidden by dense cloud when the first contact occurred, and the first view was not obtained until about 3.30, fully 25 minutes after the first contact. The disc was then obscured a little more than one-third of its surface, and the view was more or less obscured by detached masses of cloud until about 3.45, when occasional clear glimpses were obtained. A fine open rift occurred in the clouds at this time just below the Sun, and extended for a distance in azimuth of about 20 deg. with a vertical width of about 10 deg.: although the remainder of the sky was quite covered by clouds, totality miraculously occurred in this solitary space of open sky.

No shadow bands were noticed, but as the point of observation was from a hill, surrounded by deep gorges and rugged country, it is doubtful whether these would have been observable. The times were not accurately noted and no instruments were used, the prospect being too hopeless at the time of setting out to warrant carrying them. Smoked glass was therefore the only medium for observation.

The form of the corona was fairly regular except at the S.E. and N.W. points, where the streamers occurred. The corona was about half the Moon's diameter in length, and at a point between the vertex and the east point two well-marked streamers, about one and a half times the Moon's diameter in length, flexing strongly to the east, were observable all through totality. The lower streamers were nearly opposite the upper ones, but were shorter, and not so well defined.

Mr. A. A. Cox, who has attested the correctness of my sketch, observed the eclipse through the telescope of a 5-inch theodolite, and states that the chromosphere was very well marked all round the disc, displaying prominences at the base of the upper eastern streamers, and also at the north points, with minor oscillations between. His notes were published in the local paper, the

*Zeehan and Dundas Herald* of May 19th. In the same issue will be found a short description of the eclipse, contributed by me.

The darkness during totality would be equal to a medium twilight, and the air was distinctly colder. The faces of the persons present appeared ashen grey, and the distant landscape vanished into gloom.

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*Mars.* By Professor Percival Lowell. (Plate 23.)

(*Communicated by the Secretaries.*)

In order to support the hypothesis that canals, etc. etc. do not exist on Mars, the statement by M. Antoniadi has just appeared in the *Astronomische Nachrichten*, No. 4427, that the photographs of Mars taken in America at the last opposition do not show the polar cap to be brighter than the continental regions, from which it is argued that its irradiation could not swamp any dark border the cap might have, and that, therefore, the dark border was non-existent. As they show precisely the opposite, I send you a positive of these photographs, in which any eye can see that the polar cap is brighter than the "continents," and actually irradiates, in consequence, beyond the confines of the disk. This irradiation, which is apparent to the eye, prevents the narrow dark border of the cap from showing, by swamping it in irradiation glare. Any theory must be built up on facts—not the facts denied in order to support a previously conceived theory. It may also be stated that inasmuch as the light by which these photographs were taken was, in consequence of the screen used, practically that from 5400 to 5800, with its maximum at 5600, it was substantially all concentrated in the yellow of the spectrum. The light was that of the continents, which are of this colour. The polar cap, on the other hand, which is white, had its bluer radiations cut off by the screen, and did not therefore show as bright relatively as in reality it was.

We do not know from what photographs M. Antoniadi may have got his impression. It is always possible to print a positive or negative so bright that the eye finds difficulty in distinguishing between the values of the lights. The only safe way is to judge from a print dark enough for the values to disclose themselves. One would have thought, however, that to any observer of the planet the surpassing brilliancy of its polar caps compared with its bright areas must be instantly perceptible.

1910 *July* 27.

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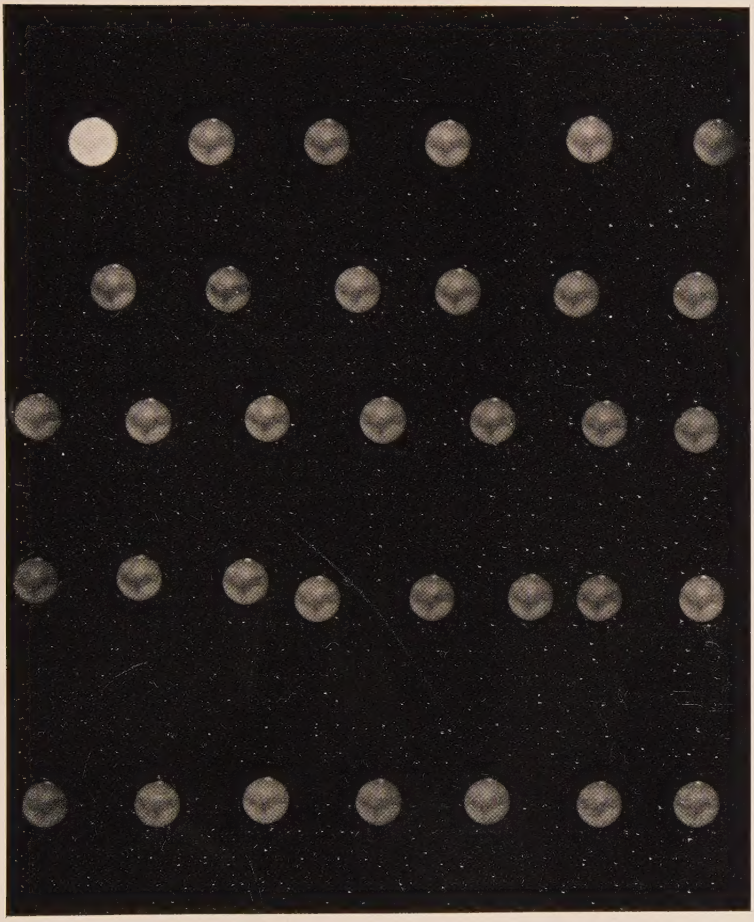

MARS. 1909 OCT. 3.

Photographs made at the Lowell Observatory.

### *Note on the nature of Saturn's Crape Ring.*

By E. M. Antoniadi.

While examining lately the *Astronomische Nachrichten* for 1889, I came across the following extract of a letter from Professor Seeliger to Dr. Anding:—"Here [in the so-called crape ring] the individual particles are much less thickly grouped [than in the bright rings], so that the limb of Saturn is visible through the interstices. Then the darkening [of the crape ring across the planet] is explained . . . . by the mere shadow cast by the particles on the globe of Saturn."*

It will be seen from this quotation that the theory of the crape ring which I had exposed in 1899† was already enunciated at least ten years previously by Professor Seeliger. As soon as I found this out, I wrote (1910 August 23) to Professor Seeliger, who kindly sent, with his reply, three valuable publications,‡ where I was glad to see how exhaustively he had treated the theory of the illumination and nature of the ring. Under such circumstances, I wish to withdraw any claims I thought I had on this subject.

1910 *September* 14.

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### *Transit of Halley's Comet*, 1910 *May* 19. *Observations made at Sydney Observatory.*

By W. E. Raymond.

The 11½-inch refractor of the Sydney Observatory was used on May 19, 1910, between 12 p.m. and 2 p.m., in the endeavour to trace Halley's Comet as it crossed the Sun's disc (time of crossing 12.22 to 1.22 p.m.).

Messrs. Walter F. Gale, of Newcastle (who had just returned from the Eclipse expedition to Brune Island, Tasmania), R. P. Sellous, B.A., Lands Department, Sydney, and the writer spent over an hour watching the Sun's disc, but not a trace of the comet could be found. Several patches of sun-spots were observed, and some of them had to be watched very minutely before any definite announcement could be made as to the possibility of their being the nucleus of the comet. Clouds interfered slightly with the observations at 1.12 p.m., but cleared again before the time announced for the termination of the transit.

Mr. W. J. McDonnell, of Mosmar, Sydney, telephoned to state that he had made a careful search of the Sun with his refractor (4¾-inch), but could detect nothing in the way of the comet.

*Sydney:*
1910 *June* 9.

* *Astr. Nachr.*, No. 2881, March 1, 1889. The brackets in the above passage are mine.

† *Monthly Notices*, 1889, pp. 498–501 and 585–588.

‡ *Zur Theorie der Beleuchtung der grossen Planeten insbesondere des Saturn*, Munich, 1887; *Theorie der Beleuchtung staubförmiger Kosmischer Massen insbesondere des Saturnringes*, Munich, 1893; and a paper in No. 4263 of the *Astr. Nachr.*

## *Note on Newcomb's Tables of Mars.*

By A. M. W. Downing, D.Sc., F.R.S.

It is now possible to apportion the respective errors, deduced from comparison with observations, which correspond to the discordances between the geocentric places of *Mars*, calculated from Leverrier's and from Newcomb's Tables of the planet at the crucial oppositions of 1907 and 1909, exhibited in my paper in *Monthly Notices*, vol. lxvii. p. 575.

From 8 meridian observations of *Mars*, 1907 July 11–30, made at the Nice Observatory (*Bulletin Astronomique*, 1908 Mars), and from 5 meridian observations, 1909 October 7–13, made at the same observatory (*Bulletin Astronomique*, 1910 Septembre), there result the following corrections to Leverrier's R.A. and Dec. as given in the *Connaissance des Temps* at the respective epochs :—

| | s | ″ |
|---|---|---|
| 1907 July | −·04 | −1·9 |
| 1909 Oct. | −·44 | −3·3 |

Hence, from the comparisons given in my paper, we have the following corrections to Newcomb's R.A. and Dec. :—

| | s | ″ |
|---|---|---|
| 1907 July | −·30 | −0·2 |
| 1909 Oct. | +·26 | +1·6 |

On my pointing out the discordances in question to Newcomb he expressed much concern, and announced his intention of looking into the matter. A little later he wrote again stating that he had discovered an error in the adopted value of one of the elements of the planet's orbit, and proposing that he should supply provisional corrections to his Tables, in anticipation of a complete revision which he would undertake when his work on the Moon was finished. To this proposal I demurred, as tending to give trouble, and to cause confusion hereafter, and suggested that it would be better to leave things as they were until the complete revision was effected. Work on *Mars* was therefore suspended, and I fear that nothing more was done before Newcomb's death.

It seems desirable now to point out that the discordances referred to above are not entirely (nor, so far as the opposition of 1909 is concerned, mainly) due to errors in Newcomb's Tables.

1910 *September* 21.

*Measures of Southern Binary Stars in* 1909.
By John Tebbutt.

The following binaries were measured here with the Cooke position and distance filar micrometer on the 8-inch equatorial during the year 1909 :—

| Star. | Fraction of Year. | Position Angle. | Distance. | Number of Evenings. |
|---|---|---|---|---|
| | | ° | ″ | |
| α Centauri . . | ·667 | 215·0 | 19·93 | 10 |
| γ Centauri . . | ·730 | ... | 1·37 | 4 |
| ,, . . | ·735 | 352·5 | ... | 5 |
| β Muscæ . . . | ·729 | ... | 1·61 | 3 |
| ,, . . | ·733 | 351·4 | ... | 4 |
| π Lupi . . . | ·797 | ... | 1·75 | 1 |
| ,, . . . | ·803 | 85·6 | ... | 2 |
| γ Circini . . . | ·826 | ... | 1·54 | 2 |
| ,, . . . | ·832 | 75·2 | ... | 6 |
| β 416 . . . | ·860 | 270·0 | 2·33 | 4 |
| γ Coronæ Australis . | ·899 | 114·1 | 2·26 | 5 |

The final results above given are derived by weighting the results for each evening according to the number of measures and the conditions for observing.

*The Observatory,*
*Windsor, N.S. Wales:*
1910 *June* 14.

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*Formulæ and Tables, applicable to all Declinations, for converting the Right Ascension and Declination of a Star into Standard Co-ordinates referred to a given Centre, and conversely.* By Dr. A. A. Rambaut, F.R.S., Radcliffe Observer.

Many methods have been proposed for converting the right ascension and declination of a star into standard co-ordinates, or, conversely, for converting standard co-ordinates into right ascension and declination. To say nothing of the various formulæ and tables given in the introductions to the different zonal photographic catalogues, or in the *Bulletin du Comité de la Carte du Ciel*, we have, comparatively recently, had tables of a general character adapted to this purpose.

(1) By Mr. Hinks ("Tables for computing Standard Co-ordinates on Photographic Plates," *Memoirs R.A.S.*, vol. lvii., part iii.);

(2) By Mons. Lagarde ("Formules et Tables pour faciliter l'Emploi des Catalogues Photographiques en Coordonnées Rectilignes," *Bulletin de la Carte du Ciel*, tome v.; and

(3) By Herr Adolf Hnatek ("Tafeln zur Bestimmung von α und

δ aus den 'Standard-Koordinaten,' des Kataloges zur photographischen Himmelskarte," *Ast. Nach.*, Nos. 4329 and 4374).

Mr. Hinks' tables are constructed chiefly for use in computing the standard co-ordinates of a star from its right ascension and declination, whilst those of Mons. Lagarde and Herr Hnatek are adapted for the reverse process, and are primarily intended to facilitate the calculation of a star's right ascension and declination from its rectilinear co-ordinates, as published in the Astrographic Catalogues.

Each of these methods has its good points, and may, in particular circumstances, be found very convenient in practice, but it appears to the present writer that a method which affords a convenient solution of both the direct and the converse problem, and formulæ which apply with equal accuracy to all parts of the sphere, and which can be used with equal facility whether the plate-centre is situated near the equator or in the immediate neighbourhood of, or even *at*, the pole itself, cannot fail to prove useful.

If $\alpha$ and $\delta$ denote the right ascension and declination of a star, $\xi$ and $\eta$ its standard rectangular co-ordinates, expressed in minutes of arc, and $A_0$, $D_0$, the right ascension and declination of the centre to which these co-ordinates are referred, then we have the following well-known relations connecting these quantities:—

$$\left.\begin{aligned} \xi &= \frac{\operatorname{cosec} 1' \,.\, \cos\delta \sin(\alpha - A_0)}{\sin\delta \sin D_0 + \cos\delta \cos D_0 \cos(\alpha - A_0)} \\ \text{and} \quad \eta &= \frac{\operatorname{cosec} 1' \{\sin\delta \cos D_0 - \cos\delta \sin D_0 \cos(\alpha - A_0)\}}{\sin\delta \sin D_0 + \cos\delta \cos D_0 \cos(\alpha - A_0)} \end{aligned}\right\} * \quad . \quad (1)$$

Let us write

$$\left.\begin{aligned} x &= \cos\delta \sin(\alpha - A_0) \\ y &= \sin\delta \cos D_0 - \cos\delta \sin D_0 \cos(\alpha - A_0) \\ z &= \sin\delta \sin D_0 + \cos\delta \cos D_0 \cos(\alpha - A_0) \end{aligned}\right\} \quad . \quad . \quad (2)$$

Further, let us take X and Y such that

$$\left.\begin{aligned} x &= \sin 1' \,.\, X \\ y &= \sin 1' \,.\, Y \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (3)$$

Then we have $\xi = X/z \,;\ \eta = Y/z \,.$ . . . . (4)

Also from (2) we find $x^2 + y^2 + z^2 = 1 \,;$ . . . . (5)

therefore $z^2 = 1 - x^2 - y^2$

or $\frac{1}{z} = \left\{ 1 - (x^2 + y^2) \right\}^{-\frac{1}{2}}$

* *Cf.* a memoir by Sir Robert Ball and Dr. Arthur A. Rambaut, read before the Royal Irish Academy, April 25, 1892, and published in the *Transactions* of the Academy, vol. xxx., part iv., pp. 235–6.

If this be expanded in a series it is easy to see that the fourth and higher powers of $x$ and $y$ may be neglected. For even if we take a plate covering as wide a field as those used for the Astrographic Catalogue and imagine a star situated at the very corner of it, the quantities X and Y will always be less than 70′. The terms of the fourth order in the expansion of $\frac{1}{z}$ are

$$\tfrac{3}{8}\sin^4 1'.(X^2+Y^2)^2$$

and if we put $X = Y = 70$ in this, its value is only

$$0{\cdot}000{,}000{,}258,$$

which cannot *under any circumstances* become sensible. We may therefore, without any loss of accuracy, write

$$\frac{1}{z} = 1 + \tfrac{1}{2}\sin^2 1'.(X^2+Y^2) \quad . \quad . \quad . \quad (6)$$

In a similar manner we find

$$z = 1 - \tfrac{1}{2}\sin^2 1'.(\xi^2+\eta^2) \quad . \quad . \quad . \quad (7)$$

And we have by means of (4)

and

$$\left.\begin{aligned} \xi &= X\{1 + \tfrac{1}{2}\sin^2 1'.(X^2+Y^2)\} \\ \eta &= Y\{1 + \tfrac{1}{2}\sin^2 1'.(X^2+Y^2)\} \\ X &= \xi\{1 - \tfrac{1}{2}\sin^2 1'.(\xi^2+\eta^2)\} \\ Y &= \eta\{1 - \tfrac{1}{2}\sin^2 1'.(\xi^2+\eta^2)\} \end{aligned}\right\} \quad . \quad . \quad (8)$$

From equations (2) and (3) we have

$$X = \operatorname{cosec} 1'.\cos\delta\sin(\alpha - A_0).$$

This term had better be computed by logarithms, and, unless extraordinary accuracy is required, six-figure logarithms will be sufficient.

When $\alpha - A_0$ is a comparatively large angle, as may be the case near the pole, there is little difficulty in getting out the logarithm of its sine from the ordinary tables. When $\alpha - A_0$ is small, however, the interpolation would be difficult. But this difficulty may be evaded for all angles up to $1200^s$ $(= 5^\circ)$ by the use of Table II., which contains the values of S calculated from the equation

$$S + \log(\alpha - A_0)^s = \log\operatorname{cosec} 1'\sin(\alpha - A_0),$$

$(\alpha - A_0)^s$ denoting the number of seconds of time in $\alpha - A_0$. In this equation S differs only by a constant from the quantity

indicated by the same symbol in Bremiker's six-place and Bruhns' seven-place logarithm tables. It differs by a constant also from the quantity which Mr. Hinks denotes by log P, and which is given in his first table.

Table II. exhibits the value of S for every tenth second of time up to $1200^s$, and by its use the conversion of $\alpha - A_0$ from time into arc is avoided.

In the neighbourhood of the pole log cos δ cannot be taken easily from the ordinary tables. Table I. is constructed to facilitate the computation in that case. The table exhibits the values of C where C is given by the equation

$$C + \log p' = \log \cos \delta,$$

$p'$ being the complement of δ expressed in minutes of arc.

Thus to find log cos δ when $\delta = 87^\circ\ 16'\ 24''{\cdot}5$
we have

$$p = 2^\circ\ 43'\ 35''{\cdot}5$$
$$p' = 163'{\cdot}5917$$
$$\log p' = 2{\cdot}213761$$
$$C = 6{\cdot}463562$$
$$\log \cos \delta = 8{\cdot}677323$$

The arrangement of this table is fairly obvious. The characteristic and the first three figures of the mantissa of C (which are the same throughout) are printed at the top of the table, and the remaining four figures of the mantissa are exhibited in the table for every minute in $p'$ up to $300'$ $(= 5^\circ)$. In this, and in Tables II., IV., and V., the seventh place of logarithms is given simply for greater accuracy in interpolating, but only six figures need be employed in the calculation.

Thus we obtain X.

We have next to consider the second of equations (2). This may be written

$$Y = \text{cosec } 1'.\ \sin(\delta - D_0) + X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0$$

But $$\sin(\delta - D_0) = \delta - D_0 - \tfrac{1}{6}(\delta - D_0)^3 + \text{etc.},$$

where all terms after the second may be neglected, since $\delta - D_0$ can never exceed $100'$. Hence if $(\delta - D_0)'$ denotes this angle expressed in minutes of arc, we have

$$\text{cosec } 1'.\ \sin(\delta - D_0) = (\delta - D_0)' - \tfrac{1}{6} \sin^2 1'(\delta - D_0)'^3,$$

or if we denote the second term on the right-hand side of this equation by Δ, we have

$$Y = (\delta - D_0)' - \Delta + X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0 \quad . \quad . \quad (9)$$

The quantity Δ is exhibited in Table III. for each minute up

to 90′. It is the same quantity expressed in minutes of arc, which in Table XXXX. of Bauschinger's *Tafeln zur theoretischen Astronomie* is given in seconds. In equation (9) it always enters with a sign opposite to that of $(\delta - D_0)'$.

Now so long as the plate does not include the pole itself, $\alpha - A_0$ is less than 90°, and therefore $\frac{1}{2}(\alpha - A_0)$ is less than 45°. Consequently the term $X \tan \frac{1}{2}(\alpha - A_0) \sin D_0$ is less than X, and can be computed very easily by the aid of logarithms. In the special case, when the plate includes the pole and extends beyond it, $\alpha - A_0$ may assume any value up to $\pm 180°$. In this case the formula (9) would become very inconvenient in the portion of the plate beyond the pole. But a very slight modification will render it available for our purpose. For if we take $A_1 = \pi + A_0$ and $D_1 = \pi - D_0$ the equations (2) become

$$\begin{aligned} -x &= \cos\delta \sin(\alpha - A_1) \\ -y &= \sin\delta \cos D_1 - \cos\delta \sin D_1 \cos(\alpha - A_1) \\ z &= \sin\delta \sin D_1 + \cos\delta \cos D_1 \cos(\alpha - A_1) \end{aligned}$$

and accordingly (9) becomes

$$-Y = (\delta - D_1)' - \Delta + X \tan \tfrac{1}{2}(\alpha - A_1) \sin D_1 \quad . \quad (10)$$

Thus if we draw a line through the pole parallel to the axis of $x$ dividing the plate into two portions, the larger of which contains the plate-centre, then the co-ordinates of all stars included in the larger portion are deduced by the original formulæ, the co-ordinates of the centre being $A_0$, $D_0$. For stars included in the smaller portion the co-ordinates are deduced from the same formulæ, but the co-ordinates of the plate-centre are taken to be $\pi + A_0$ and $\pi - D_0$, and the signs of the co-ordinates so obtained are changed. For stars situated near the dividing line it is a matter of indifference in which portion they are included.

In the immediate neighbourhood of the pole the term

$$X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0$$

may approximate very nearly to the value of X, and six-place logarithms must be used in computing its value, but for the greater part of the sky shorter tables may be employed.

As a guide to the number of decimals to be retained in calculating this term, which will depend on the declination of the centre, and the position of the star on the plate, we remark that it may be written in the form

$$\cos\delta \sin D_0 \{1 - \cos(\alpha - A_0)\} \operatorname{cosec} 1'.$$

We have also

$$z = \cos(\delta - D_0) - \cos\delta \cos D_0 \{1 - \cos(\alpha - A_0)\}.$$

Hence

$$X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0 = \{ \cos (\delta - D_0) - z \} \tan D_0 \,.\, \operatorname{cosec} 1'.$$

Since both $\cos (\delta - D_0)$ and $z$ are positive, this will be a maximum when the former is greatest and the latter least. But as $\cos (\delta - D_0) <$ unity, and since $z = 1 - \frac{1}{2} \sin^2 1' (X^2 + Y^2)$, if $2s$ denote the length (in minutes of arc) of an edge of the plate, then

$$z \not> 1 - \sin^2 1'.\, s^2.$$

Hence

$$X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0 \not> \sin 1'.\, s^2 \tan D_0.$$

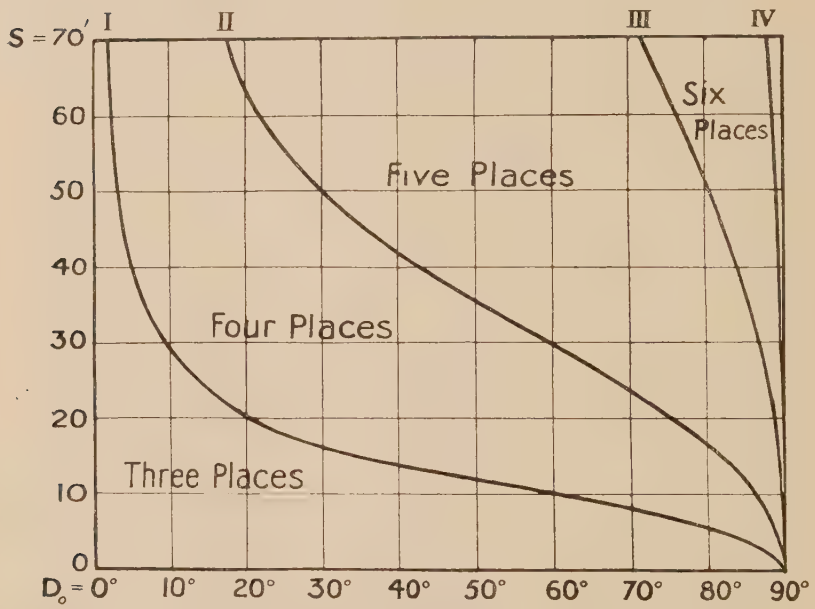


Figure to indicate the number of decimal places to be used in calculating $X \tan \frac{1}{2}(\alpha - A_0) \sin D_0$ so as to ensure the accuracy of the fourth decimal in this term.

If now we assume any value $\tau$ for this term, and taking $D_0$ as abscissa and $s$ as ordinate, we plot the curve represented by the equation

$$s^2 = \tau \operatorname{cosec} 1'.\, \cot D_0,$$

we shall define an area within which this term has a value not greater than $\tau$ even at the extreme corner of a plate measuring $2s \times 2s$.

In this way the curves I, II, III, and IV in the figure have been plotted for values of $\tau$ equal to 0·0434, 0·4343, 4·3429, and 43·4294, for which three-, four-, five-, and six-place logarithms respectively will be sufficient. Beyond curve IV an error of one

unit ( = 0″·006) in the fourth place may occur, through the use of six-figure logarithms, a possible error which in the circumstances may without scruple be ignored, but in all other cases it will be found that the number of places indicated by the figure will be more than adequate.

Thus for an astrographic plate, whose centre lies in declination 80°, six-place logarithms must be used in computing this term for a star situated near the margin of the plate. On the other hand, we see from the figure that if neither co-ordinate of the star exceeds 51′, five-place logarithms would suffice.

It is not, however, suggested that this figure should be consulted with regard to the number of decimal places to be used in the case of each individual star, but merely as a general indication, before beginning the reduction of the measures of a plate, as to the kind of tables which should be employed in order to ensure the accuracy of the last figure. Thus if an astrographic plate is taken with $D_0 = 80°$, six-place tables ought to be used, although five places would be sufficient for the greater part of it; but for a plate of the same size, such as is generally used at the Radcliffe Observatory, but which in the Radcliffe telescope covers only a field of 40′ from the centre, five places would be ample. For such a plate taken in declination 40° four-place logarithms would give all necessary precision, even at the corners.

With regard to this term there is only one further point to be noted. When $\alpha - A_0$ is a small angle we find log tan $\frac{1}{2}(\alpha - A_0)$ by the aid of the quantity T given in Table II., where

$$T + \log (\alpha - A_0)^s = \log \tan \tfrac{1}{2}(\alpha - A_0).$$

Thus we have only to add this quantity, which can be taken at sight from Table II., to log $(\alpha - A_0)^s$ in order to find log tan $\frac{1}{2}(\alpha - A_0)$.

Having thus obtained X and Y, we take $\frac{1}{2}\sin^2 1'.X^2$ and $\frac{1}{2}\sin^2 1'.Y^2$ direct from Table IV. and form their sum $\frac{1}{2}\sin^2 1'(X^2+Y^2)$.

By means of Crelle's *Rechentafeln* we then form the products

$$\tfrac{1}{2}\sin^2 1'(X^2+Y^2).X \quad \text{and} \quad \tfrac{1}{2}\sin^2 1'(X^2+Y^2).Y \quad . \quad (11)$$

and finally from equations (8) we have

$$\left.\begin{aligned} \xi &= X + \tfrac{1}{2}\sin^2 1'.(X^2+Y^2)X \\ \eta &= Y + \tfrac{1}{2}\sin^2 1'.(X^2+Y^2)Y \end{aligned}\right\} \quad . \quad . \quad (12)$$

In these expressions the products (11) have always the same sign as X and Y respectively.

Examples of the computation of $\xi$ and $\eta$ by the above method are shown on p. 664 for two stars, one situated near the equator and the other near the pole.

We have next to consider the method of finding $\alpha$ and $\delta$, being

given $A_0$, $D_0$; $\xi$ and $\eta$. For this purpose we have recourse to the fundamental equations (2), from which we deduce

$$\left.\begin{aligned} \cos\delta \sin(\alpha - A_0) &= x \\ \cos\delta \cos(\alpha - A_0) &= z\cos D_0 - y \sin D_0 \\ \sin\delta &= z \sin D_0 + y \cos D_0 \end{aligned}\right\} \quad . \quad (13)$$

Hence

$$\tan(\alpha - A_0) = \frac{x}{z\cos D_0 - y \sin D_0} \quad . \quad . \quad (14)$$

If we take $\phi$ such that

$$y = z \tan\phi$$

we have

$$\tan(\alpha - A_0) = \frac{x}{\cos(D_0 + \phi)} \cdot \frac{\cos\phi}{z}$$

$$= \frac{x}{\sqrt{1 - x^2}} \sec(D_0 + \phi).$$

By means of equations (3), (4), and (8) this becomes

$$\tan(\alpha - A_0) = \sin 1'.\xi\{1 - \tfrac{1}{2}\sin^2 1'.\eta^2\} \sec(D_0 + \phi).$$

Or if we write $X_1$ for $\xi\{1 - \frac{1}{2}\sin^2 1'.\eta^2\}$ we have

$$\tan(\alpha - A_0) = \sin 1' \, X_1 \sec(D_0 + \phi) \quad . \quad . \quad (15)$$

This is the same equation as that given by Mons. Lagarde, except that he writes $y$ for $\phi$ and $\cos y$ for $1 - \frac{1}{2}\sin^2 1'.\eta^2$.

We have

$$\phi = \tan^{-1}\left(\frac{y}{z}\right) = \tan^{-1}(\eta \sin 1')$$

$$= \eta \sin 1' - \tfrac{1}{3}\eta^3 \sin^3 1' + \text{etc.},$$

or if $\phi$ be expressed in minutes of arc, since all terms after the second may be neglected,

$$\phi = \eta - \tfrac{1}{3}\sin^2 1'.\eta^3.$$

But $\frac{1}{3}\sin^2 1'.\eta^3$ is double the quantity found in Table III., corresponding to the argument $\eta$. If, therefore, we denote this by $\Delta_\eta$ we shall have

$$\phi = \eta - 2\Delta_\eta.$$

We thus have the equations for determining $\alpha - A_0$, viz.—

$$\left.\begin{aligned} X_1 &= \xi - \tfrac{1}{2}\sin^2 1'.\eta^2.\xi \\ \phi &= \eta - 2\Delta_\eta \\ \text{and} \qquad \tan(\alpha - A_0) &= \sin 1'.X_1.\sec(D + \phi) \end{aligned}\right\} \quad . \quad (16)$$

Table V. has been constructed to facilitate the calculation of

$(\alpha - A_0)^s$ from tan $(\alpha - A_0)$ when $\alpha - A_0$ is a small angle. It exhibits the values of the quantity N, where N is given by the equation

$$N + \log \tan (\alpha - A_0) = \log (\alpha - A_0)^s$$

for every tenth second up to $1200^s (= 5^\circ)$, which will serve for astrographic plates up to $D_0 = 75^\circ\ 30'$ and for $16^{cm}$ plates in the Radcliffe telescope of 22 ft. 6 in. focal length up to $D_0 = 82^\circ\ 20'$.

The mode of using this table is best explained by an example. Suppose

$$\log \tan (\alpha - A_0) = 8{\cdot}616273.$$

Take 4·138 as an approximate value of N. Adding it to log tan $(\alpha - A_0)$ we find

$$\log (\alpha - A_0)^s = 2{\cdot}754 \ldots$$

and $\therefore$ $$(\alpha - A_0)^s = 568{\cdot} \ldots$$

Entering the table with this as argument we find

$$N = 4{\cdot}138087$$

and $$\log \tan (\alpha - A_0) = 8{\cdot}616273$$

$$\therefore \quad \log (\alpha - A_0)^s = 2{\cdot}754360$$

or $$(\alpha - A_0)^s = 568^s{\cdot}015$$

Since log tan $5^\circ = 8{\cdot}941952$ we see that, so long as log tan $(\alpha - A_0)$ is not greater than this, the value of $(\alpha - A_0)^s$ may be obtained by means of Table V.

If log tan $(\alpha - A_0)$ is *greater* than 8·941952 and *less* than 1·058048 we find $\alpha - A_0$ without difficulty by interpolation from the ordinary tables. It is thus obtained in arc, and must be converted into time.

If it exceeds 1·058048 we subtract it from 10 and thus find the complement of $(\alpha - A_0)^s$ by means of Table V. This can only occur on plates taken very close to the pole. For such plates a table for log tan $\frac{1}{2}(\alpha - A_0)$ with argument $(\alpha - A_0)^s$ and extending from $\alpha - A_0 = 5^h\ 40^m$ to $\alpha - A_0 = 6^h\ 20^m$ can be easily constructed (since the rate of change of log tan $\frac{1}{2}(\alpha - A_0)$ is nearly uniform over this range), and will obviate the necessity of converting $\alpha - A_0$ from time into arc in calculating X tan $\frac{1}{2}(\alpha - A_0)$ sin $D_0$ when $\alpha - A_0$ lies between $85^\circ$ and $95^\circ$.

To find $\delta - D_0$ we have

$$X = \xi - \tfrac{1}{2} \sin^2 1'(\xi^2 + \eta^2).\xi$$
$$Y = \eta - \tfrac{1}{2} \sin^2 1'(\xi^2 + \eta^2).\eta$$

and

$$\text{cosec } 1'.\ \sin (\delta - D_0) = Y - X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0.$$

Hence

$$(\delta - D_0)' = \{Y - X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0\} + \Delta \quad . \quad . \quad (17)$$

where $\Delta$ is the quantity taken from Table III. with

$$Y - X \tan \tfrac{1}{2}(\alpha - A_0) \sin D_0$$

as argument. $\Delta$ is always applied with the same sign as this quantity, so as to increase its absolute value.

Examples of the computation of $\alpha$ and $\delta$ by the above method are shown on p. 665 for the same two stars as before.

Computation of $\xi$ and $\eta$.

*When* $\alpha - A_0 \not> 1200^s$.

| | |
|---|---|
| $A_0$ | $21^h\ 17^m\ 20^s$ |
| $D_0$ | $-3°\ 24'$ |
| Star | Strassburg (A.G.) 7440 |
| $\alpha$ | $21^h\ 15^m\ 0^s{\cdot}89$ |
| $\delta$ | $-3°\ 15'\ 29''{\cdot}3$ |
| $\alpha - A_0$ | $-2^m\ 19^s{\cdot}11$ |
| $\delta - D_0$ | $+8'\ 30''{\cdot}7$ |
| Log cos $\delta$ | 9·999297 |
| Log $(\alpha - A_0)^s$ | 2·143358 |
| (Table II.) S | 9·397933 |
| Log X | 1·540588 |
| Log $(\alpha - A_0)^s$ | 2·1434 |
| (Table II.) T | 5·5606 |
| Log sin $D_0$ | 8·7731 |
| Log X tan $\frac{1}{2}(\alpha - A_0)$ sin $D_0$ | 8·0177 |
| Table IV. $\frac{1}{2}\sin^2 1'.X^2$ | 0·000051 |
| Table IV. $\frac{1}{2}\sin^2 1'.Y^2$ | ·000003 |
| $\frac{1}{2}\sin^2 1'(X^2+Y^2)$ | 0·000054 |
| X | $-34''{\cdot}7206$ |
| $\frac{1}{2}\sin^2 1'(X^2+Y^2).X$ | 19 |
| $\xi$ | $-34''{\cdot}7225$ |
| $(\delta - D_0)'$ | $+8'{\cdot}5117$ |
| (Table III.) $\Delta$ | 0 |
| X tan $\frac{1}{2}(\alpha - A_0)$ sin $D_0$ | $-$ ·0104 |
| Y | $+8'{\cdot}5013$ |
| $\frac{1}{2}\sin^2 1'(X^2+Y^2).Y$ | 5 |
| $\eta$ | $+8'{\cdot}5018$ |

*When* $\alpha - A_0 > 1200^s$ (*Polar Stars*).

| | |
|---|---|
| $A_0$ | $13^h\ 30^m\ 0^s$ |
| $D_0$ | $+89°\ 0'$ |
| Star | λ Ursæ Min. |
| $\alpha$ | $19^h\ 22^m\ 30^s{\cdot}65$ |
| $\delta$ | $+88°\ 59'\ 15''{\cdot}96$ |
| $\alpha - A_0$ | $5^h\ 52^m\ 30^s{\cdot}65$ |
| $\delta - D_0$ | $-0'\ 44''{\cdot}04$ |
| Arc $\alpha - A_0$ | $88°\ 7'\ 39''{\cdot}75$ |
| Arc $\frac{1}{2}(\alpha - A_0)$ | 44 3 49 ·9 |
| Log cos $\delta$ | 8·247135 |
| Log sin $(\alpha - A_0)$ | 9·999768 |
| Log cosec 1″ | 3·536274 |
| Log X | 1·783177 |
| Log tan $\frac{1}{2}(\alpha - A_0)$ | 9·985806 |
| Log sin $D_0$ | 9·999934 |
| Log X tan $\frac{1}{2}(\alpha - A_0)$ sin $D_0$ | 1·768917 |
| Table IV. $\frac{1}{2}\sin^2 1'.X^2$ | 0·000156 |
| Table IV. $\frac{1}{2}\sin^2 1'.Y^2$ | ·000142 |
| $\frac{1}{2}\sin^2 1'(X^2+Y^2)$ | 0·000298 |
| X | $+60''{\cdot}6984$ |
| $\frac{1}{2}\sin^2 1'(X^2+Y^2).X$ | 181 |
| $\xi$ | $+60''{\cdot}7165$ |
| $(\delta - D_0)'$ | $-0''{\cdot}7340$ |
| (Table III.) $\Delta$ | 0 |
| X tan $\frac{1}{2}(\alpha - A_0)$ sin $D_0$ | $+58''{\cdot}7377$ |
| Y | $+58''{\cdot}0037$ |
| $\frac{1}{2}\sin^2 1'.(X^2+Y^2).Y$ | 173 |
| $\eta$ | $+58''{\cdot}0210$ |

Computation of $\alpha$ and $\delta$.

| *When* $\log\tan(\alpha - A_0) \not> 8{\cdot}941952$. | | *When* $\log\tan(\alpha - A_0) > 1{\cdot}058048$ (*Polar Stars*). | |
|---|---|---|---|
| $\xi$ . . . . | $-34'{\cdot}7225$ | $\xi$ . . . | $+60'{\cdot}7165$ |
| $\frac{1}{2}\sin^2 1'.\eta^2.\xi$ . | 1 | $\frac{1}{2}\sin^2 1'.\eta^2.\xi$ . | 86 |
| $X_1$ . . . | $-34'{\cdot}7224$ | $X_1$ . . . | $+60'{\cdot}7079$ |
| $\frac{1}{2}\sin^2 1'.\xi^2.\xi$ . | 18 | $\frac{1}{2}\sin^2 1'.\xi^2.\xi$ . | 95 |
| X . . . | $-34'{\cdot}7206$ | X . . . | $+60'{\cdot}6984$ |
| $\eta$ . . . . | $+8'{\cdot}5018$ | $\eta$ . . . . | $+58'{\cdot}0210$ |
| $\frac{1}{2}\sin^2 1'(\xi^2+\eta^2).\eta$ . | 5 | $\frac{1}{2}\sin^2 1'(\xi^2+\eta^2).\eta$ . | 173 |
| Y . . . | $+8'{\cdot}5013$ | Y . . . | $+58'{\cdot}0037$ |
| (Table III.) $2\Delta_\eta$ . | 0 | (Table III.) $2\Delta_\eta$ . | 55 |
| $\eta - 2\Delta_\eta = \phi$ . . | $+8{\cdot}5018$ | $\eta - 2\Delta_\eta = \phi$ . . | $+58{\cdot}0155$ |
| ,, . . | $+8'\ 30''{\cdot}1$ | ,, . . | $+58'\ 0''{\cdot}93$ |
| $D_0 + \phi$ . . . | $-3^\circ\ 15'\ 29''{\cdot}9$ | $D_0 + \phi$ . . . | $+89^\circ\ 58'\ 0''{\cdot}93$ |
| Table IV. $\frac{1}{2}\sin^2 1'.\xi^2$ . | $0{\cdot}000051$ | Table IV. $\frac{1}{2}\sin^2 1'.\xi^2$ . | $0{\cdot}000156$ |
| $\frac{1}{2}\sin^2 1'.\eta^2$ . | ${\cdot}000003$ | $\frac{1}{2}\sin^2 1'.\eta^2$ . | $0{\cdot}000142$ |
| $\frac{1}{2}\sin^2 1'(\xi^2+\eta^2)$ . | $0{\cdot}000054$ | $\frac{1}{2}\sin^2 1'(\xi^2+\eta^2)$ . | $0{\cdot}000298$ |
| Log sin 1′ . . | $6{\cdot}463726$ | Log sin 1′ . . | $6{\cdot}463726$ |
| Log $X_1$ . . . | $1{\cdot}540610$ | Log $X_1$ . . | $1{\cdot}783245$ |
| Log sec $(D_0+\phi)$ . | $0{\cdot}000703$ | Log sec. $(D_0+\phi)$ . | $3{\cdot}238623$ |
| | | Log tan $(\alpha - A_0)$ . | $1{\cdot}485594$ |
| Log tan $(\alpha - A_0)$ . | $8{\cdot}005039$ | Log cot $(\alpha - A_0)$ . | $8{\cdot}514406$ |
| (Table V.) N . | $4{\cdot}138319$ | (Table V.) N . | $4{\cdot}138179$ |
| Log $(\alpha - A_0)^s$ . | $2{\cdot}143358$ | Log $[6^h - (\alpha - A_0)]^s$ | $2{\cdot}652585$ |
| | | $[6^h - (\alpha - A_0)]^s$ . | $449^s{\cdot}35$ |
| (Table II.) T . | $5{\cdot}5606$ | Log tan $\frac{1}{2}(\alpha - A_0)$ . | $9{\cdot}985806$ |
| Log X . . . | $1{\cdot}5406$ | Log X . . . | $1{\cdot}783177$ |
| Log sin $D_0$ . . | $8{\cdot}7731$ | Log sin $D_0$ . . | $9{\cdot}999934$ |
| Log X tan $\frac{1}{2}(\alpha - A_0)$ sin $D_0$ | $8{\cdot}0177$ | Log X tan $\frac{1}{2}(\alpha - A_0)$ sin $D_0$ | $1{\cdot}768917$ |
| $(\alpha - A_0)^s$ . . | $-139^s{\cdot}11$ | $\alpha - A_0$ . . . | $5^h\ 52^m\ 30^s{\cdot}65$ |
| $\alpha$ . . . . | $21^h\ 15^m\ 0^s{\cdot}89$ | $\alpha$ . . . . | $19\ \ 22\ \ 30\ \ {\cdot}65$ |
| Y . . . | $+8'{\cdot}5013$ | Y . . . | $+58'{\cdot}0037$ |
| $-X\tan\frac{1}{2}(\alpha - A_0)\sin D_0$ | $+\ {\cdot}0104$ | $-X\tan\frac{1}{2}(\alpha - A_0)\sin D_0$ | $-58\ {\cdot}7377$ |
| (Table III.) $\Delta$ . | 0 | (Table III.) $\Delta$ . | 0 |
| $(\delta - D_0)'$ . . | $+8'{\cdot}5117$ | $(\delta - D_0)'$ . . | $-0'{\cdot}7340$ |
| ,, . . | $+8'\ 30''{\cdot}7$ | ,, . . | $-0'\ 44''{\cdot}04$ |
| $\delta$ . . . . | $-3^\circ\ 15'\ 29''{\cdot}3$ | $\delta$ . . . . | $+88^\circ\ 59'\ 15''{\cdot}96$ |

TABLE I.—For **C**.

$C + \log p' = \log \cos \delta$, where $p = 90° - \delta$ expressed in minutes of arc.

6·463+

| $p'$ | 0′. | 10′. | 20′. | 30′. | 40′. | 50′. | $p'$ |
|---|---|---|---|---|---|---|---|
| ′ | | | | | | | ′ |
| 0 | 726, 2 | 725, 6 | 723, 8 | 720, 7 | 716, 4 | 710, 9 | 0 |
| | 0, 0 | 0, 1 | 0, 3 | 0, 4 | 0, 5 | 0, 7 | |
| 1 | 726, 2 | 725, 5 | 723, 5 | 720, 3 | 715, 9 | 710, 2 | 1 |
| | 0, 1 | 0, 2 | 0, 3 | 0, 4 | 0, 5 | 0, 6 | |
| 2 | 726, 1 | 725, 3 | 723, 2 | 719, 9 | 715, 4 | 709, 6 | 2 |
| | 0, 0 | 0, 1 | 0, 3 | 0, 4 | 0, 5 | 0, 6 | |
| 3 | 726, 1 | 725, 2 | 722, 9 | 719, 5 | 714, 9 | 709, 0 | 3 |
| | 0, 1 | 0, 2 | 0, 3 | 0, 4 | 0, 5 | 0, 7 | |
| 4 | 726, 0 | 725, 0 | 722, 6 | 719, 1 | 714, 4 | 708, 3 | 4 |
| | 0, 0 | 0, 2 | 0, 3 | 0, 4 | 0, 6 | 0, 6 | |
| 5 | 726, 0 | 724, 8 | 722, 3 | 718, 7 | 713, 8 | 707, 7 | 5 |
| | 0, 1 | 0, 2 | 0, 3 | 0, 5 | 0, 5 | 0, 7 | |
| 6 | 725, 9 | 724, 6 | 722, 0 | 718, 2 | 713, 3 | 707, 0 | 6 |
| | 0, 1 | 0, 2 | 0, 3 | 0, 4 | 0, 6 | 0, 7 | |
| 7 | 725, 8 | 724, 4 | 721, 7 | 717, 8 | 712, 7 | 706, 3 | 7 |
| | 0, 0 | 0, 2 | 0, 3 | 0, 4 | 0, 6 | 0, 7 | |
| 8 | 725, 8 | 724, 2 | 721, 4 | 717, 4 | 712, 1 | 705, 6 | 8 |
| | 0, 1 | 0, 2 | 0, 3 | 0, 5 | 0, 6 | 0, 7 | |
| 9 | 725, 7 | 724, 0 | 721, 1 | 716, 9 | 711, 5 | 704, 9 | 9 |
| | 0, 1 | 0, 2 | 0, 4 | 0, 5 | 0, 6 | 0, 8 | |
| 10 | 725, 6 | 723, 8 | 720, 7 | 716, 4 | 710, 9 | 704, 1 | 10 |

TABLE I.—For **C** (*continued*).

6·463+

| $p'$ | 60′. | 70′. | 80′. | 90′. | 100′. | 110′. | $p'$ |
|---|---|---|---|---|---|---|---|
| ′ | | | | | | | ′ |
| 0 | 704, 1 | 696, 2 | 687, 0 | 676, 6 | 664, 9 | 652, 1 | 0 |
| | 0, 7 | 0, 9 | 1, 0 | 1, 1 | 1, 2 | 1, 4 | |
| 1 | 703, 4 | 695, 3 | 686, 0 | 675, 5 | 663, 7 | 650, 7 | 1 |
| | 0, 7 | 0, 9 | 1, 0 | 1, 1 | 1, 3 | 1, 3 | |
| 2 | 702, 7 | 694, 4 | 685, 0 | 674, 4 | 662, 4 | 649, 4 | 2 |
| | 0, 8 | 0, 9 | 1, 0 | 1, 2 | 1, 2 | 1, 4 | |
| 3 | 701, 9 | 693, 5 | 684, 0 | 673, 2 | 661, 2 | 648, 0 | 3 |
| | 0, 8 | 0, 9 | 1, 0 | 1, 1 | 1, 3 | 1, 4 | |
| 4 | 701, 1 | 692, 6 | 683, 0 | 672, 1 | 659, 9 | 646, 6 | 4 |
| | 0, 8 | 0, 9 | 1, 0 | 1, 2 | 1, 3 | 1, 4 | |
| 5 | 700, 3 | 691, 7 | 682, 0 | 670, 9 | 658, 6 | 645, 2 | 5 |
| | 0, 8 | 0, 9 | 1, 1 | 1, 2 | 1, 3 | 1, 4 | |
| 6 | 699, 5 | 690, 8 | 680, 9 | 669, 7 | 657, 3 | 643, 8 | 6 |
| | 0, 8 | 0, 9 | 1, 1 | 1, 2 | 1, 3 | 1, 5 | |
| 7 | 698, 7 | 689, 9 | 679, 8 | 668, 5 | 656, 0 | 642, 3 | 7 |
| | 0, 8 | 1, 0 | 1, 0 | 1, 2 | 1, 3 | 1, 4 | |
| 8 | 697, 9 | 688, 9 | 678, 8 | 667, 3 | 654, 7 | 640, 9 | 8 |
| | 0, 9 | 0, 9 | 1, 1 | 1, 2 | 1, 3 | 1, 4 | |
| 9 | 697, 0 | 688, 0 | 677, 7 | 666, 1 | 653, 4 | 639, 5 | 9 |
| | 0, 8 | 1, 0 | 1, 1 | 1, 2 | 1, 3 | 1, 5 | |
| 10 | 696, 2 | 687, 0 | 676, 6 | 664, 9 | 652, 1 | 638, 0 | 10 |

TABLE I.—For **C** (*continued*).

6·463+

| $p'$ | 120′. | 130′. | 140′. | 150′. | 160′. | 170′. | $p'$ |
|---|---|---|---|---|---|---|---|
| 0 | 638, 0 | 622, 6 | 606, 1 | 588, 4 | 569, 4 | 549, 1 | 0 |
| | 1, 5 | 1, 6 | 1, 7 | 1, 8 | 2, 0 | 2, 1 | |
| 1 | 636, 5 | 621, 0 | 604, 4 | 586, 6 | 567, 4 | 547, 0 | 1 |
| | 1, 5 | 1, 6 | 1, 7 | 1, 9 | 2, 0 | 2, 1 | |
| 2 | 635, 0 | 619, 4 | 602, 7 | 584, 7 | 565, 4 | 544, 9 | 2 |
| | 1, 5 | 1, 6 | 1, 7 | 1, 9 | 2, 0 | 2, 1 | |
| 3 | 633, 5 | 617, 8 | 601, 0 | 582, 8 | 563, 4 | 542, 8 | 3 |
| | 1, 5 | 1, 6 | 1, 8 | 1, 9 | 2, 0 | 2, 1 | |
| 4 | 632, 0 | 616, 2 | 599, 2 | 580, 9 | 561, 4 | 540, 7 | 4 |
| | 1, 5 | 1, 7 | 1, 8 | 1, 9 | 2, 0 | 2, 1 | |
| 5 | 630, 5 | 614, 5 | 597, 4 | 579, 0 | 559, 4 | 538, 6 | 5 |
| | 1, 6 | 1, 6 | 1, 8 | 1, 9 | 2, 0 | 2, 1 | |
| 6 | 628, 9 | 612, 9 | 595, 6 | 577, 1 | 557, 4 | 536, 5 | 6 |
| | 1, 5 | 1, 7 | 1, 8 | 1, 9 | 2, 0 | 2, 2 | |
| 7 | 627, 4 | 611, 2 | 593, 8 | 575, 2 | 555, 4 | 534, 3 | 7 |
| | 1, 6 | 1, 7 | 1, 8 | 1, 9 | 2, 1 | 2, 2 | |
| 8 | 625, 8 | 609, 5 | 592, 0 | 573, 3 | 553, 3 | 532, 1 | 8 |
| | 1, 6 | 1, 7 | 1, 8 | 2, 0 | 2, 1 | 2, 2 | |
| 9 | 624, 2 | 607, 8 | 590, 2 | 571, 3 | 551, 2 | 529, 9 | 9 |
| | 1, 6 | 1, 7 | 1, 8 | 1, 9 | 2, 1 | 2, 2 | |
| 10 | 622, 6 | 606, 1 | 588, 4 | 569, 4 | 549, 1 | 527, 7 | 10 |

TABLE I.—For **C** (*continued*).

6·463+

| $p'$ | 180′. | 190′. | 200′. | 210′. | 220′. | 230′. | $p'$ |
|---|---|---|---|---|---|---|---|
| 0 | 527, 7 | 505, 0 | 481, 1 | 456, 0 | 429, 6 | 402, 1 | 0 |
| | 2, 2 | 2, 3 | 2, 4 | 2, 6 | 2, 7 | 2, 8 | |
| 1 | 525, 5 | 502, 7 | 478, 7 | 453, 4 | 426, 9 | 399, 3 | 1 |
| | 2, 2 | 2, 3 | 2, 5 | 2, 6 | 2, 7 | 2, 8 | |
| 2 | 523, 3 | 500, 4 | 476, 2 | 450, 8 | 424, 2 | 396, 5 | 2 |
| | 2, 2 | 2, 3 | 2, 5 | 2, 6 | 2, 7 | 2, 9 | |
| 3 | 521, 1 | 498, 0 | 473, 7 | 448, 2 | 421, 5 | 393, 6 | 3 |
| | 2, 3 | 2, 4 | 2, 5 | 2, 6 | 2, 7 | 2, 9 | |
| 4 | 518, 8 | 495, 6 | 471, 2 | 445, 6 | 418, 8 | 390, 7 | 4 |
| | 2, 3 | 2, 4 | 2, 5 | 2, 7 | 2, 8 | 2, 9 | |
| 5 | 516, 5 | 493, 2 | 468, 7 | 442, 9 | 416, 0 | 387, 8 | 5 |
| | 2, 3 | 2, 4 | 2, 5 | 2, 6 | 2, 7 | 2, 9 | |
| 6 | 514, 2 | 490, 8 | 466, 2 | 440, 3 | 413, 3 | 384, 9 | 6 |
| | 2, 3 | 2, 4 | 2, 5 | 2, 6 | 2, 8 | 2, 9 | |
| 7 | 511, 9 | 488, 4 | 463, 7 | 437, 7 | 410, 5 | 382, 0 | 7 |
| | 2, 3 | 2, 4 | 2, 5 | 2, 7 | 2, 8 | 2, 9 | |
| 8 | 509, 6 | 486, 0 | 461, 2 | 435, 0 | 407, 7 | 379, 1 | 8 |
| | 2, 3 | 2, 4 | 2, 6 | 2, 7 | 2, 8 | 2, 9 | |
| 9 | 507, 3 | 483, 6 | 458, 6 | 432, 3 | 404, 9 | 376, 2 | 9 |
| | 2, 3 | 2, 5 | 2, 6 | 2, 7 | 2, 8 | 2, 9 | |
| 10 | 505, 0 | 481, 1 | 456, 0 | 429, 6 | 402, 1 | 373, 3 | 10 |

TABLE I.—For **C** (*continued*).

6·463+

| $p'$ | 240′. | 250′. | 260′. | 270′. | 280′. | 290′. | $p'$ |
|---|---|---|---|---|---|---|---|
| ′ | | | | | | | ′ |
| 0 | 373, 3 | 343, 3 | 312, 1 | 279, 5 | 245, 9 | 210, 9 | 0 |
| | 2, 9 | 3, 1 | 3, 2 | 3, 3 | 3, 4 | 3, 5 | |
| 1 | 370, 4 | 340, 2 | 308, 9 | 276, 2 | 242, 5 | 207, 4 | 1 |
| | 3, 0 | 3, 1 | 3, 2 | 3, 3 | 3, 5 | 3, 6 | |
| 2 | 367, 4 | 337, 1 | 305, 7 | 272, 9 | 239, 0 | 203, 8 | 2 |
| | 3, 0 | 3, 1 | 3, 2 | 3, 3 | 3, 5 | 3, 6 | |
| 3 | 364, 4 | 334, 0 | 302, 5 | 269, 6 | 235, 5 | 200, 2 | 3 |
| | 3, 0 | 3, 1 | 3, 3 | 3, 4 | 3, 5 | 3, 6 | |
| 4 | 361, 4 | 330, 9 | 299, 2 | 266, 2 | 232, 0 | 196, 6 | 4 |
| | 3, 0 | 3, 1 | 3, 3 | 3, 4 | 3, 5 | 3, 6 | |
| 5 | 358, 4 | 327, 8 | 295, 9 | 262, 8 | 228, 5 | 193, 0 | 5 |
| | 3, 0 | 3, 1 | 3, 2 | 3, 3 | 3, 5 | 3, 6 | |
| 6 | 355, 4 | 324, 7 | 292, 7 | 259, 5 | 225, 0 | 189, 4 | 6 |
| | 3, 0 | 3, 1 | 3, 3 | 3, 4 | 3, 5 | 3, 6 | |
| 7 | 352, 4 | 321, 6 | 289, 4 | 256, 1 | 221, 5 | 185, 8 | 7 |
| | 3, 0 | 3, 1 | 3, 3 | 3, 4 | 3, 5 | 3, 6 | |
| 8 | 349, 4 | 318, 5 | 286, 1 | 252, 7 | 218, 0 | 182, 2 | 8 |
| | 3, 0 | 3, 2 | 3, 3 | 3, 4 | 3, 5 | 3, 7 | |
| 9 | 346, 4 | 315, 3 | 282, 8 | 249, 3 | 214, 5 | 178, 5 | 9 |
| | 3, 1 | 3, 2 | 3, 3 | 3, 4 | 3, 6 | 3, 7 | |
| 10 | 343, 3 | 312, 1 | 279, 5 | 245, 9 | 210, 9 | 174, 8 | 10 |

TABLE II.—For **S** and **T**.

$S + \log(\alpha - A_0)^s = \log \operatorname{cosec} 1' \sin(\alpha - A_0)$; $T + \log(\alpha - A_0)^s = \log \tan \frac{1}{2}(\alpha - A_0)$.

| $\alpha - A_0$. | S. | Diff. | T. | Diff. | $\alpha - A_0$. | S. | Diff. | T. | Diff. |
|---|---|---|---|---|---|---|---|---|---|
| s | | | | | s | | | | |
| 0 | 9·397940, 1 | | 5·560636, 2 | | 200 | 9·397924, 8 | | 5·560643, 8 | |
| | | 0, 1 | | 0, 0 | | | 1, 6 | | 0, 8 |
| 10 | 940, 0 | 0, 1 | 636, 2 | 0, 0 | 210 | 923, 2 | 1, 7 | 644, 6 | 0, 8 |
| 20 | 939, 9 | 0, 2 | 636, 2 | 0, 1 | 220 | 921, 5 | 1, 7 | 645, 4 | 0, 9 |
| 30 | 939, 7 | 0, 2 | 636, 3 | 0, 2 | 230 | 919, 8 | 1, 7 | 646, 3 | 0, 9 |
| 40 | 939, 5 | 0, 4 | 636, 5 | 0, 2 | 240 | 918, 0 | 1, 8 | 647, 2 | 0, 9 |
| 50 | 939, 1 | 0, 4 | 636, 7 | 0, 2 | 250 | 916, 1 | 1, 9 | 648, 1 | 0, 9 |
| | | 0, 4 | | 0, 2 | | | 1, 9 | | 1, 0 |
| 60 | 938, 7 | 0, 5 | 636, 9 | 0, 2 | 260 | 914, 2 | 2, 0 | 649, 1 | 1, 0 |
| 70 | 938, 2 | 0, 6 | 637, 1 | 0, 3 | 270 | 912, 2 | 2, 1 | 650, 1 | 1, 1 |
| 80 | 937, 6 | 0, 6 | 637, 4 | 0, 3 | 280 | 910, 1 | 2, 2 | 651, 2 | 1, 1 |
| 90 | 937, 0 | 0, 8 | 637, 7 | 0, 4 | 290 | 907, 9 | 2, 3 | 652, 3 | 1, 1 |
| 100 | 936, 2 | 0, 8 | 638, 1 | 0, 4 | 300 | 905, 6 | 2, 3 | 653, 4 | 1, 1 |
| | | 0, 8 | | 0, 4 | | | 2, 3 | | 1, 2 |
| 110 | 935, 4 | 0, 8 | 638, 5 | 0, 4 | 310 | 903, 3 | 2, 4 | 654, 6 | 1, 2 |
| 120 | 934, 6 | 1, 0 | 638, 9 | 0, 5 | 320 | 900, 9 | 2, 5 | 655, 8 | 1, 2 |
| 130 | 933, 6 | 1, 0 | 639, 4 | 0, 5 | 330 | 898, 4 | 2, 6 | 657, 0 | 1, 3 |
| 140 | 932, 6 | 1, 1 | 639, 9 | 0, 6 | 340 | 895, 8 | 2, 6 | 658, 3 | 1, 3 |
| 150 | 931, 5 | 1, 2 | 640, 5 | 0, 6 | 350 | 893, 2 | 2, 7 | 659, 6 | 1, 4 |
| 160 | 930, 3 | 1, 3 | 641, 1 | 0, 6 | 360 | 890, 5 | 2, 8 | 661, 0 | 1, 4 |
| 170 | 929, 0 | 1, 3 | 641, 7 | 0, 7 | 370 | 887, 7 | 2, 9 | 662, 4 | 1, 4 |
| 180 | 927, 7 | 1, 4 | 642, 4 | 0, 7 | 380 | 884, 8 | 3, 0 | 663, 8 | 1, 5 |
| 190 | 926, 3 | 1, 5 | 643, 1 | 0, 7 | 390 | 881, 8 | 3, 0 | 665, 3 | 1, 5 |
| 200 | 9·397924, 8 | | 5·560643, 8 | | 400 | 9·397878, 8 | | 5·560666, 8 | |

TABLE II.—For **S** and **T** *continued.*

$S + \log(\alpha - A_0)^s = \log \operatorname{cosec} 1' \sin(\alpha - A_0)$ ; $T + \log(\alpha - A_0)^s = \log \tan \frac{1}{2}(\alpha - A_0)$.

| $\alpha - A_0$. | S. | Diff. | T. | Diff. | $\alpha - A_0$. | S. | Diff. | T. | Diff. |
|---|---|---|---|---|---|---|---|---|---|
| s | | | | | s | | | | |
| 400 | 9·397878, 8 | | 5·560666, 8 | | 800 | 9·397695, 0 | | 5·560758, 7 | |
| | | 3, 1 | | 1, 5 | | | 6, 1 | | 3, 1 |
| 410 | 875, 7 | 3, 2 | 668, 3 | 1, 6 | 810 | 688, 9 | 6, 3 | 761, 8 | 3, 1 |
| 420 | 872, 5 | 3, 2 | 669, 9 | 1, 6 | 820 | 682, 6 | 6, 3 | 764, 9 | 3, 2 |
| 430 | 869, 3 | 3, 3 | 671, 5 | 1, 7 | 830 | 676, 3 | 6, 4 | 768, 1 | 3, 2 |
| 440 | 866, 0 | 3, 3 | 673, 2 | 1, 7 | 840 | 669, 9 | 6, 5 | 771, 3 | 3, 2 |
| 450 | 862, 6 | 3, 4 | 674, 9 | 1, 7 | 850 | 663, 4 | 6, 6 | 774, 5 | 3, 3 |
| | | 3, 5 | | 1, 8 | | | 6, 6 | | 3, 3 |
| 460 | 859, 1 | 3, 6 | 676, 7 | 1, 8 | 860 | 656, 8 | 6, 7 | 777, 8 | 3, 3 |
| 470 | 855, 5 | 3, 6 | 678, 5 | 1, 8 | 870 | 650, 2 | 6, 7 | 781, 1 | 3, 3 |
| 480 | 851, 9 | 3, 7 | 680, 3 | 1, 8 | 880 | 643, 5 | 6, 7 | 784, 4 | 3, 4 |
| 490 | 848, 2 | 3, 8 | 682, 1 | 1, 9 | 890 | 636, 8 | 6, 9 | 787, 8 | 3, 4 |
| 500 | 844, 4 | 3, 9 | 684, 0 | 1, 9 | 900 | 629, 9 | 6, 9 | 791, 2 | 3, 5 |
| | | | | | | | | | |
| 510 | 840, 5 | 3, 9 | 685, 9 | 2, 0 | 910 | 623, 0 | 7, 0 | 794, 7 | 3, 5 |
| 520 | 836, 6 | 4, 1 | 687, 9 | 2, 0 | 920 | 616, 0 | 7, 1 | 798, 2 | 3, 5 |
| 530 | 832, 5 | 4, 1 | 689, 9 | 2, 1 | 930 | 608, 9 | 7, 2 | 801, 7 | 3, 6 |
| 540 | 828, 4 | 4, 1 | 692, 0 | 2, 1 | 940 | 601, 7 | 7, 2 | 805, 3 | 3, 6 |
| 550 | 824, 3 | 4, 3 | 694, 1 | 2, 1 | 950 | 594, 5 | 7, 3 | 808, 9 | 3, 7 |
| 560 | 820, 0 | 4, 3 | 696, 2 | 2, 2 | 960 | 587, 2 | 7, 4 | 812, 6 | 3, 7 |
| 570 | 815, 7 | 4, 4 | 698, 4 | 2, 2 | 970 | 579, 8 | 7, 5 | 816, 3 | 3, 7 |
| 580 | 811, 3 | 4, 5 | 700, 6 | 2, 2 | 980 | 572, 3 | 7, 5 | 820, 0 | 3, 8 |
| 590 | 806, 8 | 4, 5 | 702, 8 | 2, 3 | 990 | 564, 8 | 7, 6 | 823, 8 | 3, 8 |
| 600 | 802, 3 | 4, 7 | 705, 1 | 2, 3 | 1000 | 557, 2 | 7, 8 | 827, 6 | 3, 9 |
| 610 | 797, 6 | 4, 7 | 707, 4 | 2, 4 | 1010 | 549, 4 | 7, 7 | 831, 5 | 3, 9 |
| 620 | 792, 9 | 4, 8 | 709, 8 | 2, 4 | 1020 | 541, 7 | 7, 8 | 835, 4 | 3, 9 |
| 630 | 788, 1 | 4, 9 | 712, 2 | 2, 4 | 1030 | 533, 9 | 7, 9 | 839, 3 | 4, 0 |
| 640 | 783, 2 | 5, 0 | 714, 6 | 2, 4 | 1040 | 526, 0 | 8, 1 | 843, 3 | 4, 0 |
| 650 | 778, 2 | 4, 9 | 717, 1 | 2, 5 | 1050 | 517, 9 | 8, 1 | 847, 3 | 4, 0 |
| 660 | 773, 3 | 5, 1 | 719, 6 | 2, 5 | 1060 | 509, 8 | 8, 1 | 851, 3 | 4, 1 |
| 670 | 768, 2 | 5, 2 | 722, 1 | 2, 6 | 1070 | 501, 7 | 8, 3 | 855, 4 | 4, 1 |
| 680 | 763, 0 | 5, 2 | 724, 7 | 2, 6 | 1080 | 493, 4 | 8, 3 | 859, 5 | 4, 1 |
| 690 | 757, 8 | 5, 3 | 727, 3 | 2, 7 | 1090 | 485, 1 | 8, 4 | 863, 6 | 4, 2 |
| 700 | 752, 5 | 5, 4 | 730, 0 | 2, 7 | 1100 | 476, 7 | 8, 4 | 867, 8 | 4, 3 |
| 710 | 747, 1 | 5, 5 | 732, 7 | 2, 7 | 1110 | 468, 3 | 8, 5 | 872, 1 | 4, 3 |
| 720 | 741, 6 | 5, 6 | 735, 4 | 2, 8 | 1120 | 459, 8 | 8, 6 | 876, 4 | 4, 3 |
| 730 | 736, 0 | 5, 6 | 738, 2 | 2, 8 | 1130 | 451, 2 | 8, 8 | 880, 7 | 4, 3 |
| 740 | 730, 4 | 5, 8 | 741, 0 | 2, 8 | 1140 | 442, 4 | 8, 7 | 885, 0 | 4, 4 |
| 750 | 724, 6 | 5, 7 | 743, 8 | 2, 9 | 1150 | 433, 7 | 8, 9 | 889, 4 | 4, 4 |
| 760 | 718, 9 | 5, 8 | 746, 7 | 2, 9 | 1160 | 424, 8 | 8, 9 | 893, 8 | 4, 5 |
| 770 | 713, 1 | 6, 0 | 749, 6 | 3, 0 | 1170 | 415, 9 | 9, 0 | 898, 3 | 4, 5 |
| 780 | 707, 1 | 6, 0 | 752, 6 | 3, 0 | 1180 | 406, 9 | 9, 1 | 902, 8 | 4, 5 |
| 790 | 701, 1 | 6, 1 | 755, 6 | 3, 0 | 1190 | 397, 8 | 9, 1 | 907, 3 | 4, 5 |
| 800 | 9·397695, 0 | | 5·560758, 7 | 3, 1 | 1200 | 9·397388, 7 | | 5·560911, 9 | 4, 6 |

TABLE III.—For $\Delta = \theta' - \frac{\sin \theta}{\sin 1'}$.

| θ. | Δ | Diff. | θ. | Δ | Diff. | θ. | Δ | Diff. |
|---|---|---|---|---|---|---|---|---|
| 0′ | 0′·0000, 0 | | 30′ | 0′·0003, 8 | | 60′ | 0′·0030, 5 | |
| | | | | | 0, 4 | | | 1, 5 |
| 1 | 00, 0 | | 31 | 04, 2 | 0, 4 | 61 | 32, 0 | 1, 6 |
| 2 | 00, 0 | | 32 | 04, 6 | 0, 5 | 62 | 33, 6 | 1, 7 |
| 3 | 00, 0 | | 33 | 05, 1 | 0, 4 | 63 | 35, 3 | 1, 7 |
| 4 | 00, 0 | | 34 | 05, 5 | 0, 5 | 64 | 37, 0 | 1, 7 |
| 5 | 00, 0 | | 35 | 06, 0 | | 65 | 38, 7 | |
| | | | | | 0, 6 | | | 1, 8 |
| 6 | 00, 0 | | 36 | 06, 6 | 0, 5 | 66 | 40, 5 | 1, 9 |
| 7 | 00, 0 | 0, 1 | 37 | 07, 1 | 0, 6 | 67 | 42, 4 | 1, 9 |
| 8 | 00, 1 | 0, 0 | 38 | 07, 7 | 0, 7 | 68 | 44, 3 | 2, 0 |
| 9 | 00, 1 | 0, 0 | 39 | 08, 4 | 0, 6 | 69 | 46, 3 | 2, 1 |
| 10 | 00, 1 | | 40 | 09, 0 | | 70 | 48, 4 | |
| | | 0, 1 | | | 0, 7 | | | 2, 1 |
| 11 | 00, 2 | 0, 0 | 41 | 09, 7 | 0, 7 | 71 | 50, 5 | 2, 1 |
| 12 | 00, 2 | 0, 1 | 42 | 10, 4 | 0, 8 | 72 | 52, 6 | 2, 3 |
| 13 | 00, 3 | 0, 1 | 43 | 11, 2 | 0, 8 | 73 | 54, 9 | 2, 3 |
| 14 | 00, 4 | 0, 1 | 44 | 12, 0 | 0, 8 | 74 | 57, 2 | 2, 3 |
| 15 | 00, 5 | | 45 | 12, 8 | | 75 | 59, 5 | |
| | | 0, 1 | | | 0, 9 | | | 2, 4 |
| 16 | 00, 6 | 0, 1 | 46 | 13, 7 | 0, 9 | 76 | 61, 9 | 2, 5 |
| 17 | 00, 7 | 0, 1 | 47 | 14, 6 | 1, 0 | 77 | 64, 4 | 2, 5 |
| 18 | 00, 8 | 0, 2 | 48 | 15, 6 | 1, 0 | 78 | 66, 9 | 2, 6 |
| 19 | 01, 0 | 0, 1 | 49 | 16, 6 | 1, 0 | 79 | 69, 5 | 2, 7 |
| 20 | 01, 1 | | 50 | 17, 6 | | 80 | 72, 2 | |
| | | 0, 2 | | | 1, 1 | | | 2, 8 |
| 21 | 01, 3 | 0, 2 | 51 | 18, 7 | 1, 1 | 81 | 75, 0 | 2, 8 |
| 22 | 01, 5 | 0, 2 | 52 | 19, 8 | 1, 2 | 82 | 77, 8 | 2, 8 |
| 23 | 01, 7 | 0, 2 | 53 | 21, 0 | 1, 2 | 83 | 80, 6 | 3, 0 |
| 24 | 01, 9 | 0, 3 | 54 | 22, 2 | 1, 3 | 84 | 83, 6 | 3, 0 |
| 25 | 02, 2 | | 55 | 23, 5 | | 85 | 86, 6 | |
| | | 0, 3 | | | 1, 3 | | | 3, 1 |
| 26 | 02, 5 | 0, 3 | 56 | 24, 8 | 1, 3 | 86 | 89, 7 | 3, 2 |
| 27 | 02, 8 | 0, 3 | 57 | 26, 1 | 1, 4 | 87 | 92, 9 | 3, 2 |
| 28 | 03, 1 | 0, 3 | 58 | 27, 5 | 1, 5 | 88 | 96, 1 | 3, 3 |
| 29 | 03, 4 | 0, 4 | 59 | 29, 0 | 1, 5 | 89 | ·0099, 4 | 3, 4 |
| 30 | 0 ·0003, 8 | | 60 | 0 ·0030, 5 | | 90 | 0 ·0102, 8 | |

TABLE IV.—For $\frac{1}{2}\sin^2 1'.\theta^2$.

| $\theta$. | $\frac{1}{2}\sin^2 1'.\theta^2$. | Diff. | $\theta$. | $\frac{1}{2}\sin^2 1'.\theta^2$. | Diff. | $\theta$. | $\frac{1}{2}\sin^2 1'.\theta^2$. | Diff. |
|---|---|---|---|---|---|---|---|---|
| 0′ | 0·000000, 0 | | 25′ | 0·000026, 4 | | 50′ | 0·000105, 8 | |
| | | 0, 0 | | | 2, 2 | | | 4, 2 |
| 1 | 000, 0 | 0, 2 | 26 | 028, 6 | 2, 2 | 51 | 110, 0 | 4, 4 |
| 2 | 000, 2 | 0, 2 | 27 | 030, 8 | 2, 4 | 52 | 114, 4 | 4, 4 |
| 3 | 000, 4 | 0, 3 | 28 | 033, 2 | 2, 4 | 53 | 118, 8 | 4, 4 |
| 4 | 000, 7 | 0, 4 | 29 | 035, 6 | 2, 5 | 54 | 123, 4 | 4, 6 |
| 5 | 001, 1 | 0, 4 | 30 | 038, 1 | 2, 6 | 55 | 128, 0 | 4, 6 |
| | | 0, 6 | | | 2, 6 | | | 4, 7 |
| 6 | 001, 5 | 0, 6 | 31 | 040, 7 | 2, 8 | 56 | 132, 7 | 4, 8 |
| 7 | 002, 1 | 0, 7 | 32 | 043, 3 | 2, 8 | 57 | 137, 5 | 4, 8 |
| 8 | 002, 7 | 0, 8 | 33 | 046, 1 | 2, 9 | 58 | 142, 3 | 5, 0 |
| 9 | 003, 4 | 0, 8 | 34 | 048, 9 | 3, 0 | 59 | 147, 3 | 5, 0 |
| 10 | 004, 2 | 0, 9 | 35 | 051, 8 | 3, 1 | 60 | 152, 3 | 5, 1 |
| | | 1, 0 | | | 3, 2 | | | 5, 2 |
| 11 | 005, 1 | 1, 1 | 36 | 054, 8 | 3, 2 | 61 | 157, 4 | 5, 3 |
| 12 | 006, 1 | 1, 1 | 37 | 057, 9 | 3, 4 | 62 | 162, 6 | 5, 4 |
| 13 | 007, 2 | 1, 2 | 38 | 061, 1 | 3, 4 | 63 | 167, 9 | 5, 4 |
| 14 | 008, 3 | 1, 3 | 39 | 064, 3 | 3, 5 | 64 | 173, 3 | 5, 6 |
| 15 | 009, 5 | 1, 4 | 40 | 067, 7 | 3, 6 | 65 | 178, 7 | 5, 6 |
| | | 1, 5 | | | 3, 7 | | | 5, 7 |
| 16 | 010, 8 | 1, 6 | 41 | 071, 1 | 3, 8 | 66 | 184, 3 | 5, 8 |
| 17 | 012, 2 | 1, 6 | 42 | 074, 6 | 3, 8 | 67 | 189, 9 | 5, 9 |
| 18 | 013, 7 | 1, 7 | 43 | 078, 2 | 4, 0 | 68 | 195, 6 | |
| 19 | 015, 3 | 1, 8 | 44 | 081, 9 | 4, 0 | 69 | 201, 4 | |
| 20 | 016, 9 | 1, 8 | 45 | 085, 7 | 4, 1 | 70 | 0·000207, 3 | |
| | | 1, 9 | | | 4, 2 | | | |
| 21 | 018, 7 | 2, 0 | 46 | 089, 5 | 4, 3 | | | |
| 22 | 020, 5 | 2, 0 | 47 | 093, 5 | 4, 4 | | | |
| 23 | 022, 4 | 2, 1 | 48 | 097, 5 | 4, 4 | | | |
| 24 | 024, 4 | 2, 2 | 49 | 101, 6 | 4, 6 | | | |
| 25 | 0·000026, 4 | | 50 | 0·000105, 8 | | | | |

TABLE V.—For **N.** $N + \log \tan (\alpha - A_0) = \log (\alpha - A_0)^s$.

| $\alpha - A_0$. | N. | Diff. | $\alpha - A_0$. | N. | Diff. | $\alpha - A_0$. | N. | Diff. | $\alpha - A_0$. | N. | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4·138+ | | | 4·138+ | | | 4·138+ | | | 4·137+ | |
| s | | | s | | | s | | | s | | |
| 0 | 333, 8 | | 300 | 264, 9 | | 600 | 058, 1 | | 900 | 713, 1 | |
| | | 0, 0 | | | 4, 7 | | | 9, 3 | | | 13, 9 |
| 10 | 333, 8 | 0, 3 | 310 | 260, 2 | 4, 8 | 610 | 048, 8 | 9, 3 | 910 | 699, 2 | 14, 0 |
| 20 | 333, 5 | 0, 4 | 320 | 255, 4 | 5, 0 | 620 | 039, 5 | 9, 7 | 920 | 685, 2 | 14, 2 |
| 30 | 333, 1 | 0, 5 | 330 | 250, 4 | 5, 1 | 630 | 029, 8 | 9, 6 | 930 | 671, 0 | 14, 3 |
| 40 | 332, 6 | 0, 7 | 340 | 245, 3 | 5, 3 | 640 | 020, 2 | 9, 9 | 940 | 656, 7 | 14, 5 |
| 50 | 331, 9 | 0, 8 | 350 | 240, 0 | 5, 4 | 650 | 010, 3 | 10, 1 | 950 | 642, 2 | 14, 7 |
| 60 | 331, 1 | 1, 0 | 360 | 234, 6 | 5, 6 | 660 | 000, 2 | 10, 2 | 960 | 627, 5 | 14, 8 |
| 70 | 330, 1 | 1, 2 | 370 | 229, 0 | 5, 7 | 670 | *990, 0 | 10, 3 | 970 | 612, 7 | 14, 9 |
| 80 | 328, 9 | 1, 3 | 380 | 223, 3 | 5, 9 | 680 | 979, 7 | 10, 5 | 980 | 597, 8 | 15, 2 |
| 90 | 327, 6 | 1, 4 | 390 | 217, 4 | 6, 1 | 690 | 969, 2 | 10, 7 | 990 | 582, 6 | 15, 3 |
| 100 | 326, 2 | 1, 6 | 400 | 211, 3 | 6, 2 | 700 | 958, 5 | 10, 8 | 1000 | 567, 3 | 15, 4 |
| 110 | 324, 6 | 1, 8 | 410 | 205, 1 | 6, 4 | 710 | 947, 7 | 10, 9 | 1010 | 551, 9 | 15, 5 |
| 120 | 322, 8 | 1, 9 | 420 | 198, 7 | 6, 5 | 720 | 936, 8 | 11, 1 | 1020 | 536, 4 | 15, 8 |
| 130 | 320, 9 | 2, 1 | 430 | 192, 2 | 6, 6 | 730 | 925, 7 | 11, 4 | 1030 | 520, 6 | 15, 9 |
| 140 | 318, 8 | 2, 2 | 440 | 185, 6 | 6, 8 | 740 | 914, 3 | 11, 3 | 1040 | 504, 7 | 16, 0 |
| 150 | 316, 6 | 2, 4 | 450 | 178, 8 | 7, 0 | 750 | 903, 0 | 11, 6 | 1050 | 488, 7 | 16, 2 |
| 160 | 314, 2 | 2, 5 | 460 | 171, 8 | 7, 1 | 760 | 891, 4 | 11, 8 | 1060 | 472, 5 | 16, 4 |
| 170 | 311, 7 | 2, 7 | 470 | 164, 7 | 7, 3 | 770 | 879, 6 | 11, 9 | 1070 | 456, 1 | 16, 5 |
| 180 | 309, 0 | 2, 8 | 480 | 157, 4 | 7, 4 | 780 | 867, 7 | 12, 0 | 1080 | 439, 6 | 16, 7 |
| 190 | 306, 2 | 3, 0 | 490 | 150, 0 | 7, 6 | 790 | 855, 7 | 12, 2 | 1090 | 422, 9 | 16, 8 |
| 200 | 303, 2 | 3, 1 | 500 | 142, 4 | 7, 8 | 800 | 843, 5 | 12, 4 | 1100 | 406, 1 | 16, 9 |
| 210 | 300, 1 | 3, 3 | 510 | 134, 6 | 7, 9 | 810 | 831, 1 | 12, 4 | 1110 | 389, 2 | 17, 2 |
| 220 | 296, 8 | 3, 5 | 520 | 126, 7 | 8, 0 | 820 | 818, 7 | 12, 7 | 1120 | 372, 0 | 17, 3 |
| 230 | 293, 3 | 3, 6 | 530 | 118, 7 | 8, 2 | 830 | 806, 0 | 12, 8 | 1130 | 354, 7 | 17, 3 |
| 240 | 289, 7 | 3, 7 | 540 | 110, 5 | 8, 3 | 840 | 793, 2 | 13, 0 | 1140 | 337, 4 | 17, 7 |
| 250 | 286, 0 | 3, 9 | 550 | 102, 2 | 8, 6 | 850 | 780, 2 | 13, 0 | 1150 | 319, 7 | 17, 7 |
| 260 | 282, 1 | 4, 1 | 560 | 093, 6 | 8, 6 | 860 | 767, 2 | 13, 3 | 1160 | 302, 0 | 17, 9 |
| 270 | 278, 0 | 4, 2 | 570 | 085, 0 | 8, 8 | 870 | 753, 9 | 13, 4 | 1170 | 284, 1 | 18, 1 |
| 280 | 273, 8 | 4, 4 | 580 | 076, 2 | 9, 0 | 880 | 740, 5 | 13, 6 | 1180 | 266, 0 | 18, 1 |
| 290 | 269, 4 | 4, 5 | 590 | 067, 2 | 9, 1 | 890 | 726, 9 | 13, 8 | 1190 | 247, 9 | 18, 5 |
| 300 | 264, 9 | | 600 | 058, 1 | | 900 | 713, 1 | | 1200 | 229, 4 | |

* From 0s to 660s the characteristic and first three figures in the mantissa of N are 4·138. Beyond 660s they are 4·137.

LIST OF ADDITIONS

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# MONTHLY NOTICES

OF THE

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## ANNOUNCEMENT OF PAPERS RECEIVED.

Post-cards, giving the titles of such Papers as have been received or promised up to the Tuesday preceding the day of the Ordinary Meeting, will be sent to such Fellows who inform the Assistant Secretary of their wish to receive them.

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## *MEMOIRS.*

Fellows are informed that in future a separate application for each volume of the *Memoirs* will not be required. Any Fellow sending his name to the Assistant Secretary will receive the volumes to which he is entitled, as they are issued, without further application.

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